APPENDIX B:

DESIGN AND CONSTRUCTION MANAGEMENT PRACTICES FOR CONCRETE PAVEMENTS

B-1. Introduction.

a. *Content.* This document discusses recommended practices for design and construction management for concrete pavements, including design staffing, design studies, preparation of plans, specifications and Engineering Considerations and Instructions for Field Personnel (ECIFP), design review, preconstruction preparation, construction staffing and responsibilities, pavement completion documentation, and Transportation Systems Mandatory Center of Expertise (TSMCX) services. A sample specification requirements for listed aggregate sources, a sample ECIFP, a sample preconstruction pavement workshop agenda, and a list of post-construction pavement materials completion data are included in the annexes.

b. *Scope.* Concrete pavements include airfield runways, taxiways, aprons and related pavements, roads, streets, parking areas, vehicle and tank hardstands, tank trails and similar transportation surfaces. The design and construction management practices described in this document are intended for application to new or replacement pavements that can be classified as medium to large (over 2000 m^3 or 2500 yd^3), or critical projects. Portions of this document can be applied to O&M projects, hangar floors, and smaller new or replacement pavement projects. Maintenance and repair of pavements are not covered in this document.

c. *TSMCX Services.* ER 1110-34-1, "Transportation Systems Mandatory Center of Expertise," describes the authority, policy and responsibilities of the TSMCX. This document also presents information on mandatory design reviews, criteria waiver policy and procedures, criteria development, and TSMCX services for design and construction assistance. The 12 Apr 1996 and 12 Jun 1997 CEMP-ET Memoranda, Subject: Military Construction Design Review Policy for Airfield, Railroad and Roadway Projects," establish HQUSACE policy for design review by the TSMCX. The "Transportation News" is a periodic publication of the TSMCX to provide information on transportation technology issues. The TSMCX maintains Indefinite Delivery Type (IDT) Contracts for airfield and roadway pavement design, construction management and other related services, that are available for use by Districts. Each FOA responsible for military design and construction should have a POC designated for coordination with the TSMCX. Questions concerning TSMCX services should be directed to:

US Army Corps of Engineers
Transportation Systems Center
215 North 17th Street

Phone: 402-221-7260
Fax: 402-221-7261

Homepage: http://www.mrd.usace.army.mil/tsmcx/tsmcx.html
Omaha, NE 68102-4978

B-2. Design and Design Documents.

a. General. ER 1110-345-100, "Design Policy for Military Construction," establishes policies, responsibilities and procedures for the design of military facilities, including concrete pavements. ER 1110-1-12, “Quality Management,” provides general policy for quality of design services, and describes design documents. TM 5-822-7, “Standard Practice For Concrete Pavements,” provides information on the materials and construction procedures for concrete pavements. ER 1110-3-107, "Design of Military Airfield Pavements," sets forth policy concerning design of military airfield pavements with respect to operational or other design information. Corps participation in preparation and review with the using activity of the Department of Defense (DD) Form 1391, "Military Construction Project Data," is a key element in successful pavement design and construction. The TSMCX should be contacted for DD Form 1391 development when possible, and should be kept current with DD Form 1391 and relevant design issues as they arise during the project life. The design process for concrete pavements is similar to conventional military projects, with a few exceptions. Following selection of a designer, early studies for design include geotechnical investigations and a geotechnical or foundation report, materials studies and a materials report, leading to a design analysis report. This is followed by preparation of plans and specifications, an Engineering Considerations and Instructions for Field Personnel (ECIFP), a cost estimate, and design reviews. Full coordination and intensive involvement with the using activity throughout the design process is a critical element for successful pavement projects. Site visits by the designers at the beginning and during design are essential for all projects. A site visit by the designers is mandatory for all concrete pavements. Construction personnel should attend these site visits when feasible. Design Quality Control plans are required for all military projects, including pavements.

b. Pavement design training for designers. Training courses, seminars or workshops relating to concrete pavement design, evaluation and/or construction are available from a variety of sources. PROSPECT courses, "Pavement and Drainage Design and Construction," and “Advanced Concepts in Pavement Design and Evaluation,” are conducted by CEWES and managed by the Huntsville Engineering and Support Center. The TSMCX provides Pavement-Transportation Computer Assisted Structural Engineering (PCASE) regional seminars, and airfield design and layout workshops for specific projects, when requested.

c. Design agents. Designers of concrete paving projects may be in-house or Architect-Engineer (A-E) firms. Design firms specializing in pavement design can provide competent design of military concrete pavements. Most A-E firms that do not specialize in pavements are unfamiliar with pavement concerns and criteria, and may require some time to become proficient

in pavement requirements. The TSMCX generally maintains one or more IDT contracts with A-E firm(s) experienced in design of pavements. These IDT contracts are available for use by Corps Districts. Knowledgeable, experienced design staff, whether in-house or A-E, are critical for successful concrete pavement projects. Typical concrete pavement design teams consist of (several roles may be combined in one person):

Pavement layout engineer
Geotechnical engineer
Materials engineer
Mechanical/electrical engineer

d. Geotechnical report. Geotechnical reports are prepared on most military projects as a record of foundation investigations and foundation design for that project. TM 5-822-5, "Pavement Design for Roads, Streets, Walks, and Open Storage Areas," discusses preliminary investigations for these types of pavements. TM 5-825-3, "Rigid Pavements for Airfields," covers preliminary investigation, subgrade considerations, base courses, soil stabilization or modification, and evaluation of foundation support. The results of these and related investigations should be presented in the geotechnical report. TM 5-825-1, “General provisions for Airfield/Heliport Pavement Design,” presents geotechnical information that must be included in the design analysis for these types of pavements.

e. Materials studies. Early in the design period, concrete materials studies are required to determine the availability of aggregates and allied materials, the quality and durability of the aggregates and other materials, and the properties of these materials in concrete. TM 5-822-7, "Standard Practice for Concrete Pavements," describes concrete materials for pavements, as well as requirements for "approval of aggregates." TM 5-825-1, “General Provisions for Airfield/Heliport Pavement Design,” describes materials information that is presented in the design analysis. Information from these studies is generally presented in an office report. Conclusions and recommendations from these studies include the design material properties for the concrete pavement, and provide the basis for specification preparation for the concrete pavement. Description of typical contents of the office report follow.

(1) Project description and concrete pavement requirements. This includes a summary description of the pavement to be constructed, including site requirements, dimensions, quantities of concrete and materials, and special logistical problems.

(2) Environmental conditions. This section contains information on climatic and other environmental conditions at the site which may affect the concrete, including rainfall, hot weather conditions, cold weather conditions, deicer applications, snow plow usage, sulfate attack, and possible jet blast conditions.

(3) Aggregate sources. All potential sources of aggregate for concrete are described in this section, including possible Government-owned sources, commercial sources, and undeveloped sources. Aggregate sources typically may include alluvial deposits, wash deposits, glacial deposits, and rock quarries. Aggregate source names generally refer to a particular reach of alluvial deposit, wash or glacial deposit, or to a particular quarry. There may be several aggregate producers in a particular aggregate source. Aggregate information can be obtained from a variety of sources, including Technical Memorandum 6-370, “Test Data - Concrete Aggregates and Stone Riprap in Continental United States and Alaska," state transportation department resources, USGS reports or maps, state geologist reports or maps, county or state planning agencies, local test laboratories, and individual aggregate producers. Information provided concerning each source might include estimated volume of aggregate available, maximum aggregate size, percentage of sand in the source, general mineralogy of the source, production capacities, percentage crushed particles, sizes of aggregate produced, and costs for various aggregate sizes. Field inspections of the source by a materials engineer or geologist provides valuable preliminary information on the probable suitability of the aggregate. In particular, early identification of deleterious materials in the aggregate can be made during a field inspection. EM 1110-2-2000, "Standard Practice for Concrete," provides useful information and guidance on general aggregate quality and durability, including discussion on the forms of alkali-aggregate reactivity, and similar aggregate problems. Deleterious materials in aggregates used for airfield pavements can create significant Foreign Object Damage (FOD) to aircraft. Detailed knowledge of the potential for FOD from all aggregates considered for use is an essential feature of materials studies for airfield pavements. TM 5-822-7, "Standard Practice for Concrete Pavements," provides information on materials, and specifically on deleterious materials in aggregates. CEGS 02753, “Concrete Pavements for Airfields and Other Heavy-Duty Pavements,” provides additional information on deleterious materials.

(4) Cementitious material sources. Likely sources of cement and pozzolan are described in this portion of the materials report. Information provided on available cement sources includes types of cement available at the plants, availability of low alkali cement, haul distance, and delivered cost. Information on available pozzolans includes types available, which generally will be a type F or C flyash, production capacity, typical loss on ignition (LOI, a measure of carbon content), haul distance, and delivered cost.

(5) Water, admixtures and other materials. Available sources of on-site water for construction are described here, including approximate quantity, reliability, and suitability for use in concrete. Use of commercial admixtures is discussed, particularly air entraining and water reducing admixtures. Unusual admixtures or other materials may be considered or required for some projects, such as fast track airfield pavements where existing airfields may be shut down only for very short time periods.

(6) Ready mix concrete sources. For smaller jobs, the use of readymix concrete may be considered, to avoid mobilization of relatively expensive central mix plants typically used on medium to large size projects. When applicable, this section provides information on the sources and distances from local readymix plants to the project.

(7) Aggregate test results. Small bagged samples of potential aggregate should be taken during field inspections, for preliminary petrographic examination. If preliminary examinations and information indicate an aggregate source should be considered for use, then bulk samples are obtained and transported to the test laboratory. The results of aggregate physical quality, chemical, petrographic and deleterious material testing are evaluated together to determine the suitability of each aggregate for the purpose and environmental conditions the concrete will be subjected to. EM 1110-2-2000, "Standard Practice for Concrete," provides guidance on aggregate testing. TM 5-822-7, “Standard Practice for Concrete Pavements,” provides additional guidance on aggregate testing, including guidance for deleterious materials testing. The results from concrete aggregate testing should be recorded in Technical Memorandum 6-370, “Test Data - Concrete Aggregates and Stone Riprap in Continental United States and Alaska.

(8) Mixture proportioning test results. Sufficient time is seldom available to complete aggregate testing prior to the initiation of mixture proportioning studies. Both aggregate testing and mixture proportioning studies, conducted by the Government and directed by the materials engineer, are generally pursued concurrently during the design stage. Mixture proportioning studies are essential for concrete pavements to determine the potential concrete properties for design, to evaluate the cost efficiency and suitability of each aggregate source, to establish which aggregates can be used (and possibly listed in the specifications), and to assist in the development of cost estimates for the project. Poor aggregate quality may limit the strength of the concrete to moderate or even low values. Mixture proportioning studies are also used to examine the range of strength obtainable with a particular aggregate. Typically three water-cement ratios are selected for mixture proportioning that will bracket the water-cement ratio expected to provide the strength level desired. These water-cement ratios should be widely spaced so that a full range of strength performance is provided. The same water-cement ratios should be used for all the aggregates investigated to allow for direct comparison of the strength performance of the aggregates. The "efficiency" of each aggregate source can be evaluated by comparing similar mixes using the different aggregates. This can be done by comparing the “cement efficiency” of each mixture, that is, the strength divided by the cementitious material content of the mixture.

(9) Service record studies. Study of the performance of aggregates in existing concrete pavements in the region of the project must be conducted to provide information on the long-term durability and performance of those aggregates. These pavements could include older pavements at the installation, local state highways, county or city roads, or pavements at local airports. Records of aggregates and other materials used in these older pavements are generally difficult to

locate, although many state transportation departments do keep these records. Sometimes the aggregate source can be reliably determined by simple observation of the aggregate in the pavement. Service record studies can provide information on popouts, weatherouts, D-cracking, and other deleterious material-related problems, abrasion resistance, shrinkage, skid-resistance and other aggregate-related performance. Typical data collected during service record studies includes:

Pavement information:
- Pavement designation
- Installation location
- Date constructed
- Contractor and contract number
- Source of fine aggregate
- Source of coarse aggregate
- Source of cementitious materials
- Nominal maximum size of aggregate
- Mixture proportions
- Strength information
- Joint spacing
- Thickness
- Traffic type and frequency
- Latest condition rating, if applicable

Pavement condition:
- Cracking
- Crazing
- Spalling
- Popouts
- Weatherouts
- Soundness
- Abrasion
- Surface texture
- Overall condition

(10) Conclusions and recommendations. The conclusions and recommendations in the materials report are used to prepare the specifications. This section typically includes recommendations on whether to list aggregate sources in the specifications (see Annex 1), what sources should be listed, what cementitious materials to allow, source(s) of water, allowable admixtures, air content, maximum aggregate size, any unusual requirements for aggregates or aggregate deleterious materials, what strength and age to specify, and the like.

f. Design analysis. The design analysis of the concrete pavement should be described in an official document, including requirements from the geotechnical report and the materials office report. ER 1110-345-100, "Design Policy for Military Construction," and specifically ER 1110-345-700, "Design Analyses, Drawings and Specifications" addresses policy for design analyses for military projects, including transmittal of the final design analysis to the using activity upon completion of the project. EI 02C013, “Planning and Design of Airfields and Heliports," (draft) provides general provisions, criteria and policy for airfields and heliports. ETL 1110-3-394, "Aircraft Characteristics for Airfield-Heliport Design and Evaluation," provides information on aircraft characteristics for layout, design, or evaluation of airfield and heliport pavement systems. ETL 1110-3-380, "Standard Distribution of Military Airfield Pavement Design and Evaluation Information," provides guidance for the distribution of airfield and heliport pavement design analyses.

(1) The most current design criteria is listed on the USACE internet homepage, and is available through routine channels. Criteria is also available from the Construction Criteria Base (CCB) maintained by National Institute of Building Sciences (NIBS), and from TECHINFO, maintained by the Huntsville Engineering and Support Center. Any special requirements for a pavement project should be coordinated with the using activity and MAJCOM, and with the TSMCX.

(2) The TSMCX should be fully involved during all stages of design, from development of the DD Form 1391, through initial project concept design, to final design development and design reviews. The TSMCX should be contacted during design for any interim design criteria changes that may be in memorandum or ETL form, and not yet a part of more formal criteria. Funding for TSMCX reviews must be included in the project funds.

g. Drawings. ER 1110-345-100, "Design Policy for Military Construction," and specifically ER 1110-345-700, "Design Analyses, Drawings and Specifications" addresses policy for design drawings. TM 5-825-1, "General Provisions for Airfield/Heliport Pavement Design," provides an outline of design drawings. DG 1110-3-204 (AFP 88-7), “Design Guide for Army and Air Force Airfields, Pavements, Railroads, Storm Drainage and Earthwork,” contains typical details and some example layouts that may be used for concrete pavement designs. Typical design drawings for concrete pavements include the following:

Plan view of project (including contractor work area and concrete plant area)
Pavement borrow areas
Pavement layout
Pavement removal plan
Pavement removal details
Pavement elevations and sections

Pavement profiles
Pavement elevations at all joint intersections
Pavement joint plan
Pavement cross sections
Pavement joint details
Pavement joint sealant details

Joint intersection elevations should be developed and shown on the drawings to insure adequate drainage is provided, and that correct elevations are available to the contractor. Detailed pavement joint plans should be provided in the drawings. Joint plans should not be left to contractors to determine in the field. Use of typical sections has been determined to be an inadequate means of showing pavement design sections. Multiple sections should be shown on the drawings wherever there is a change or transition from one pavement section to another. Designers should coordinate with the using activity and the TSMCX regarding special requirements for each project.

h. Specifications. ER 1110-345-100, "Design Policy for Military Construction," and specifically ER 1110-345-700, "Design Analyses, Drawings and Specifications," address policy for design specifications, including policy for deviations from guide specifications. Guide specifications are listed on the USACE Internet homepage, and are available from the CCB and from TECHINFO. CEGS-02753, "Concrete Pavements for Airfields and Other Heavy-Duty Pavements," and CEGS-02754, "Concrete Pavements for Small projects," are used for all concrete pavements. Although guide specifications for concrete pavements are written to address almost all possible features expected to be a part of a project, including notes to guide specification preparation, the project specifications must be carefully examined by experienced engineers to insure that all features are covered, that non-applicable items are deleted, and that specification provisions are appropriate for the specific project. In addition to general information useful for specification preparation, TM 5-822-7, "Standard Practice for Concrete Pavement," contains provisions for use of "listed sources" of aggregate. Annex 1 contains sample wording for "listed aggregate sources" that can be included in the specification special provisions or general requirements. Aggregate sources are not listed on all concrete pavement projects, and are seldom listed on small projects. Where listed sources are not used, the aggregate quality requirements must be carefully and completely specified. Preparation of specifications for concrete pavement, including joint sealants, should be closely coordinated with the using activity.

i. Engineering Considerations and Instructions for Field Personnel (ECIFP). Following completion of design (plans and specifications), an ECIFP should be prepared by the designer and the materials engineer. ER 1110-1-12, “Quality Management,” provides a list of design documents, including the ECIFP. The ECIFP is used to convey to the field office special design concepts, assumptions, concerns and instructions required for construction. The document

establishes a basis for communication and coordination between the designers and construction personnel. The document should discuss the design analysis, including geotechnical issues and concrete materials considerations, and should provide recommendations for construction procedures for the construction office, but should not merely repeat the design analysis, other available information or the specifications requirements. Typical ECIFP documents for concrete pavement follow the organizational structure of the specification, and might include the following:

Submittals, particularly concerning equipment and materials
Concrete strength and mix proportions
Concrete slump
Concrete mixing plant and concrete production
Pavers and paving
Finishing
Curing
Pavement thickness and surface tolerances
Pavement repair and replacement
Joints and sealing
Quality control
Quality assurance
Project staffing
Engineering support to construction
Site visits by the designer(s)

An example ECIFP is included in Annex 2. Preparation of an ECIFP should be closely coordinated with the using activity and the TSMCX.

j. Cost estimates. ER 1110-345-100, "Design Policy for Military Construction," and specifically ER 1110-1-1300, "Cost Engineering Policy and General Requirements," and ER 1110-3-1300, "Military Programs Cost Engineering," address policy for cost engineering and construction cost estimates.

k. Criteria waivers. Most criteria waivers involve airfield pavements. EI 02C013, “Planning and Design of Airfields and Heliports," (draft) provides guidance for waivers for Army, Air Force, Navy and Marine Corps airfields. AFR 86-5, "Planning Criteria and Waivers for Airfield Support Facilities," provides guidance for Air Force airfield support facilities.

(1) General. Waivers are required for any design deviations from published airfield criteria. Waiver procedures have been established to ensure that Corps designs and Army airfields meet Federal Aviation Regulations, DOD directives, Army policy and host nation requirements.

Waivers can be requested by the owner of the airfield or in rare instances by the design District. Examples of conditions possibly requiring criteria waivers include the following:

Siting of all runway, runway extensions, helipads and other airfield features.

Siting of any facility, tower, fixed or mobile object which protrudes into airfield clear zones.

Aircraft operational facilities lighting and marking not meeting criteria.

Air traffic control and navigational aids facilities not meeting criteria.

TM 5-822-7, "Standard Practice for Concrete Pavements," contains information concerning options for "deleterious substances" in concrete aggregates that may be requested by waiver.

(2) Waiver requests initiated by the design District. These waiver requests are sent to the TSMCX for review and approval. Requests not approved by the TSMCX will be returned to the district. Requests approved by the TSMCX will be forwarded to the appropriate office indicated in EI 02C013, "Planning and Design of Airfields and Heliports." Waivers not related to airfields will be forwarded to HQUSACE (CEMP-ET) for review and approval. The project design analysis shall include copies of all waivers.

(3) TSMCX assistance. The TSMCX provides technical engineering assistance to Corps districts preparing waiver requests. Districts are encouraged to use this service.

l. Design review. ER 1110-345-100, "Design Policy for Military Construction," provides general design review policy. HQUSACE policy (References) requires TSMCX review of all airfield pavement projects, and review of all projects where the roadway pavement cost is over $3,000,000. The TSMCX should be fully involved with design review from project inception, including preparation of DD Form 1391. TSMCX design review responsibility should be identified in the DD Form 1391 Special Design Instructions (SDI) for all projects meeting the mandatory design review requirements described above under TSMCX services. Cost of TSMCX reviews must be included in the district project funding. Bidability, Constructability, Operability and Environmental (BCOE) reviews, including field office review, are required and are discussed in ER 1180-1-6, “Construction Quality Management.”

B-3. Preconstruction Preparation.

a. General. Pavement construction practices are distinctly different from military vertical construction, and generally require different expertise in the field. Advance preparation for any type of construction is important to a successful project, but can be considered even more critical

for this type of construction. Since field construction offices do not manage this kind of project on a regular basis, specialized training is important to provide the field staff with the specialized knowledge required to manage a concrete pavement construction project. Preconstruction workshops can also be an important step in providing additional knowledge and understanding of the requirements for a specific paving project. The TSMCX can provide training and workshop assistance and information. Quality assurance planning is discussed in ER 1180-1-6, "Construction Quality Management."

b. Pavement construction training for field staff. Training on concrete pavement construction practices is essential for field staff, but can be difficult to schedule without significant advance notice of approaching pavement construction. A PROSPECT course on Pavement and Drainage Design and Construction provides information for both flexible and rigid pavements. Other organizations occasionally offer courses related to concrete pavement construction, such as the National Highway Institute. A PROSPECT exportable course, "Quality Verification: Concrete," on videotape, covers general concrete inspection and verification , including concrete paving.

c. Preconstruction pavement workshop. A short workshop on concrete paving conducted at the construction office is an excellent way to provide essential information on design, materials, construction equipment, practices and testing to the field staff, and to gather feedback from the field staff and the contractor on field conditions. These workshops, typically lasting about one day, are generally conducted by TSMCX staff, with the designer and field staff. Subject matter includes design intent, plans and specifications, the ECIFP, discussion of anticipated and proposed construction equipment, activities and procedures, and can include the Contractor briefing Corps staff on proposed equipment, operations, and testing. Discussion and resolution of critical issues with the Contractor can be greatly facilitated by these workshops. A typical agenda of a preconstruction paving workshop is included in Annex 3. The using activity should be invited to these meetings.

B-4. Construction.

Excellent designs, plans and specifications alone will not provide a high quality pavement. Without well trained and experienced construction personnel, given adequate resources, given adequate time to consistently and continuously monitor contractor efforts, and the authority to direct those contractor efforts, the concrete pavement product will often be less than satisfactory to the Corps and the using activity. Some key elements for high quality pavement construction management are discussed below. Partnering between all elements, including the contractor, the Corps construction staff, the designers, testing laboratories, and the using activity, can contribute significantly to construction of a high quality pavement. ER 1180-1-6, "Construction Quality Management," provides general guidance for establishing quality management procedures,

including an outline for quality assurance plans, required on all military projects, including concrete pavements.

a. Construction staffing. The most important element in producing a high quality pavement is a well trained and experienced construction staff. Construction staffing must be carefully thought out well in advance of the concrete pavement construction, taking into consideration the complexity and demands of the project, experience and training levels of available personnel, the availability of assistance from design staff, contract support, and other staffing resources. For a moderate to large-sized concrete paving project, the following staffing is considered the minimum adequate for during concrete placement:

(1) Field engineer. The field engineer should be dedicated only to the one paving project, especially for medium to large projects. The field engineer directs all quality assurance activities.

(2) Quality assurance representatives (QAR). Depending on the nature and size of the project, two to three full time QAR are required to monitor contractor concrete construction activities and performance. Large slipform paving projects generally require at least one QAR for the paver and one for the concrete plant, aggregate production and related activities. A single well trained QAR may be sufficient for subsurface preparation and construction, depending on the complexity of the work. Use of soil cement or drainage layers may require additional quality assurance, as well as support from the designer/materials engineer. Features other than concrete construction may require other specialized quality assurance. Field engineer and quality assurance services can be acquired through service contracts, but the qualifications and experience of the individuals to provide the services should be carefully scrutinized, and these individuals should be thoroughly trained in the specific procedures and objectives of the specific project. At least one QAR or the field engineer must be experienced and thoroughly knowledgeable in heavy duty pavement construction, particularly for airfield pavements. Field staff that must service multiple projects are not generally able to adequately manage and inspect moderate to large concrete paving projects, such as runways, taxiways and aprons, or large roads and hardstands. Additional quality assurance services are available from TSMCX IDT contracts.

b. Surveying and smoothness measurement. A survey party chief and two person crew is generally required on larger projects for checking concrete elevations and alignment, and straightedging where required. These services are normally specified as contractor responsibilities, but may performed by the Government, using either district survey staff or by a service contract. Where profileograph measurements are required on the completed pavement surface, service contracts will usually be required to provide crews experienced with this specialized equipment. Profileograph services are generally included in the specifications as a contractor requirement. TSMCX IDT contracts are available for quality assurance activities.

c. Quality assurance laboratory. Government quality assurance testing can be provided by Government personnel, but is more often provided by a service contract. Concrete field testing technicians should all be at a minimum ACI Grade I Certified and laboratory testing technicians should be ACI Grade I or II Certified Laboratory Technicians. It may be useful to require a registered engineer to sign all test reports. A laboratory inspection conducted prior to construction by Corps laboratory personnel is mandatory (ER 1110-1-261, "Quality Assurance of Laboratory Testing Procedures").

d. Design/materials engineer construction assistance. On-site field assistance by the design and/or materials engineer or the TSMCX is recommended at critical stages in pavement construction, particularly for medium to large or complex projects. These stages might include:

Preconstruction workshops and meetings
At start of existing pavement removal, if applicable
Base course and drainage layer construction
Inspection of concrete mixing plant and paver prior to placement
At start of concrete paving
At key stages of concrete placement
At start of joint sealing
Pavement completion

The materials engineer should be consulted at the start of mixture proportioning studies, and final mixture proportions should be reviewed by the materials engineer prior to approval or placement. The design engineer/materials engineer and the TSMCX are resources available to the field office for troubleshooting at any time during construction, for pavement workmanship assistance, and for periodic field data review, especially concerning concrete strength data.

e. Inspection. Routine inspection of subsurface layer construction, and continuous, full time inspection of concrete placement is required for high quality concrete pavement construction. At least one of the QAR or the field engineer must be experienced and trained in concrete pavement, and should be supplemented by assistance in the field at key intervals by design/materials engineers or the TSMCX. TSMCX IDT contracts are available for construction management and inspection services.

B-5. Pavement Completion Documentation.

The collection and retention of specific construction data and information is essential to insure that materials and mixtures used in construction can be evaluated for long-term durability and performance, and to insure that less than successful practices, equipment or materials used by a

contractor become lessons learned and become the basis for criteria changes. Several methods or programs, described below, can assist in the collection of construction data and information for application to future projects and in the correction of pavement standards, practices or criteria.

a. As-built drawings and design analysis. ER 1110-345-700, "Design Analyses, Drawings and Specifications" provides policy regarding as-built drawings furnished to the using activity. All modifications to design joint layouts must be shown on the as-built drawings to insure accurate information is presented for future pavement removal or replacement requirements, such as for later installation of utilities. ER 1110-345-700, "Design Analyses, Drawings and Specifications" requires transmittal of the final design analysis to the using activity upon completion.

b. Pavement construction completion data. Following completion of concrete pavements, the pavement designer or materials engineer must acquire construction data from the field construction office and must include this data in a "Pavement Construction Completion Data" sheet. A sample of the contents of this data sheet is included in Annex 4. This document summarizes construction information on the pavement, including pavement and concrete data, aggregate physical tests, gradations and allied data, mixture proportions, and concrete strength data. This is an essential document, not only for use in evaluating quality of the pavement product, but more importantly for future pavement service record surveys. Knowing the sources of materials and other information about pavements constructed earlier enables designers and materials engineers to assess the long-term durability of aggregates, other materials, and material combinations, for use on future projects. These documents should be retained permanently in the district engineering office, and a copy should be sent to the using activity and the TSMCX.

c. Lessons learned report. Following completion of concrete pavements, a lessons learned office report should be prepared, listing and describing successful and less than successful construction practices, equipment or materials used by the Contractor. This report should be retained in the district engineering and construction offices, with a copy forwarded to the TSMCX. It is understandable why districts are reluctant to describe less than successful pavement experiences, however, unless these experiences are passed on to USACE elements who can make necessary changes to criteria or pavement practices, these valuable lessons will continue to be lost, and the same less than successful practices will likely be repeated on future work.

d. Design criteria changes. ER 1110-345-100, "Design Policy for Military Construction," discusses ENG Form 3078, "Recommended Changes to Engineering Documents," for changes to drawings and specifications, and DA Form 2028, "Recommended Changes to Publications and Blank Forms," for changes to criteria. These forms should be submitted to HQUSACE (CEMP-ET), generally by the design or materials engineer, with a copy to the TSMCX, to describe necessary changes in design standards, guide specifications or other documents or criteria for concrete pavements.

e. Test data. Technical Memorandum 6-370, "Concrete Aggregates and Stone Riprap in Continental United States and Alaska," provides a compilation of concrete aggregate and riprap stone test data. The use of a specific aggregate source and aggregate test results on a paving project should be reported on the aggregate data summary sheets. These documents must be filled out by the district annually for transmittal to WES, using information provided by the materials engineer, or may be filled out by the design or materials engineer.